Maryland Upper Eastern Shore

Final Version for 1985-2002 Data
February 2, 2004

Prepared by: Basin Summary Team and Chesapeake Bay Program
Tidal Monitoring and Analysis Workgroup
Contact: Beth Ebersole, Maryland Department of Natural Resources bebersole@dnr.state.md.us

Maryland Upper Eastern Shore Basin Characteristics

Maryland's Upper Eastern Shore drains 1,298 square miles of land including all of Kent County and portions of Cecil, Queen Anne's, and Talbot Counties in the Upper Eastern portion of the State. Major water bodies include the Miles, Chester, Elk, Bohemia, Sassafras, and Northeast Rivers. There are numerous tributary creeks and several large embayments (Eastern Bay, Prospect Bay, Crab Alley Bay). Back Creek forms the western end of the Chesapeake and Delaware Canal. The Chesapeake and Delaware generally transports water toward Delaware River, but can transport either way. The basin lies both in the Piedmont physiographic province and the Coastal Plain province.

Census population for the basin in 2000 was 125,000. Major population centers in the basin include Elkton, Chestertown, Grasonville, Centreville, and North East.

The predominant land use in the Upper Eastern Shore basin is classified as agricultural (58 percent). Forested and wetland areas are the second largest land use at 32 percent. Around 10 percent of the basin is comprised of urban lands.

Approximately 58 percent of the Upper Eastern Shore's land area is devoted to agricultural use. A series of Best Management Practices (BMPs) have been planned in the basin to help reduce non-point source pollution. BMP implementation for conservation tillage, cover crops, retirement and treatment of highly erodible land, stream protection, and erosion and sediment control are all making good progress toward Tributary Strategy goals. For other BMPs, such as those for animal waste management systems, forested and grassed buffers, and stormwater management measures, progress has been slower, and in some cases, nonexistent.

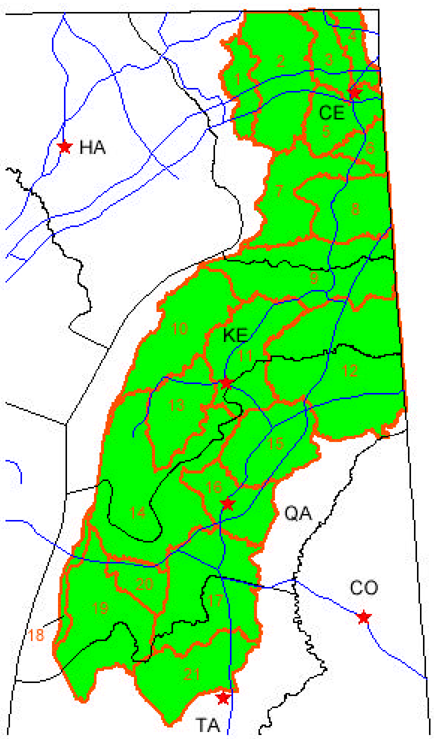
Around 10 percent of the basin is comprised of urban (developed) lands. Approximately 79 percent of the development in the Upper Eastern Shore is considered low intensity. Eighteen percent of the developed land is commercially developed, and about three percent is high intensity development.

Approximately 82 percent of the basin's housing is in rural areas, with most of the remainder in urban areas. Not surprisingly, the majority of the basin's housing (between 60 and 70 percent) also relies on septic systems and wells as opposed to municipal water systems. As a result, point sources are not the dominant contributor of nutrient loads in the Upper Eastern Shore. There are six major wastewater treatment facilities in the basin. Biological Nutrient Removal (BNR) has been implemented at one facility, and the BNR is planned for the remaining five by 2005.

Appendix A contains graphs of nutrient loads from the basin's major wastewater treatment facilities.

As of 2002, the most significant contributor of nitrogen to Maryland's Upper Eastern Shore was agricultural sources (74 percent) (Figure UES4). Following that were point sources (9 percent) and urban sources (6 percent). For phosphorus, the largest contributor was also agriculture (73 percent) (Figure UES5). This was followed by mixed open lands (11 percent), urban sources (9 percent), and point sources (6 percent). Agriculture was also the largest source of sediment, contributing 89 percent of the basin's sediment load (Figure UES6).

Figure UES1- Locator Map of the Upper Eastern Shore Basin



Number	Watershed Name
1	Furnace Bay
2	North East River
3	Little Elk Creek
4	Big Elk Creek
5	Upper Elk River
6	Back Creek
7	Lower Elk River
8	Bohemia River
9	Sassafras River
10	Stillpond - Fairlee
11	Middle Chester River
12	Upper Chester River
13	Langford Creek
14	Lower Chester River
15	Southeast Creek
16	Corsica River
17	Wye River
18	Kent Island - Bay Drainage
19	Eastern Bay
20	Kent Narrows
21	Miles River

Figure UES2 – 2000 Land Use in the Upper Eastern Shore Basin

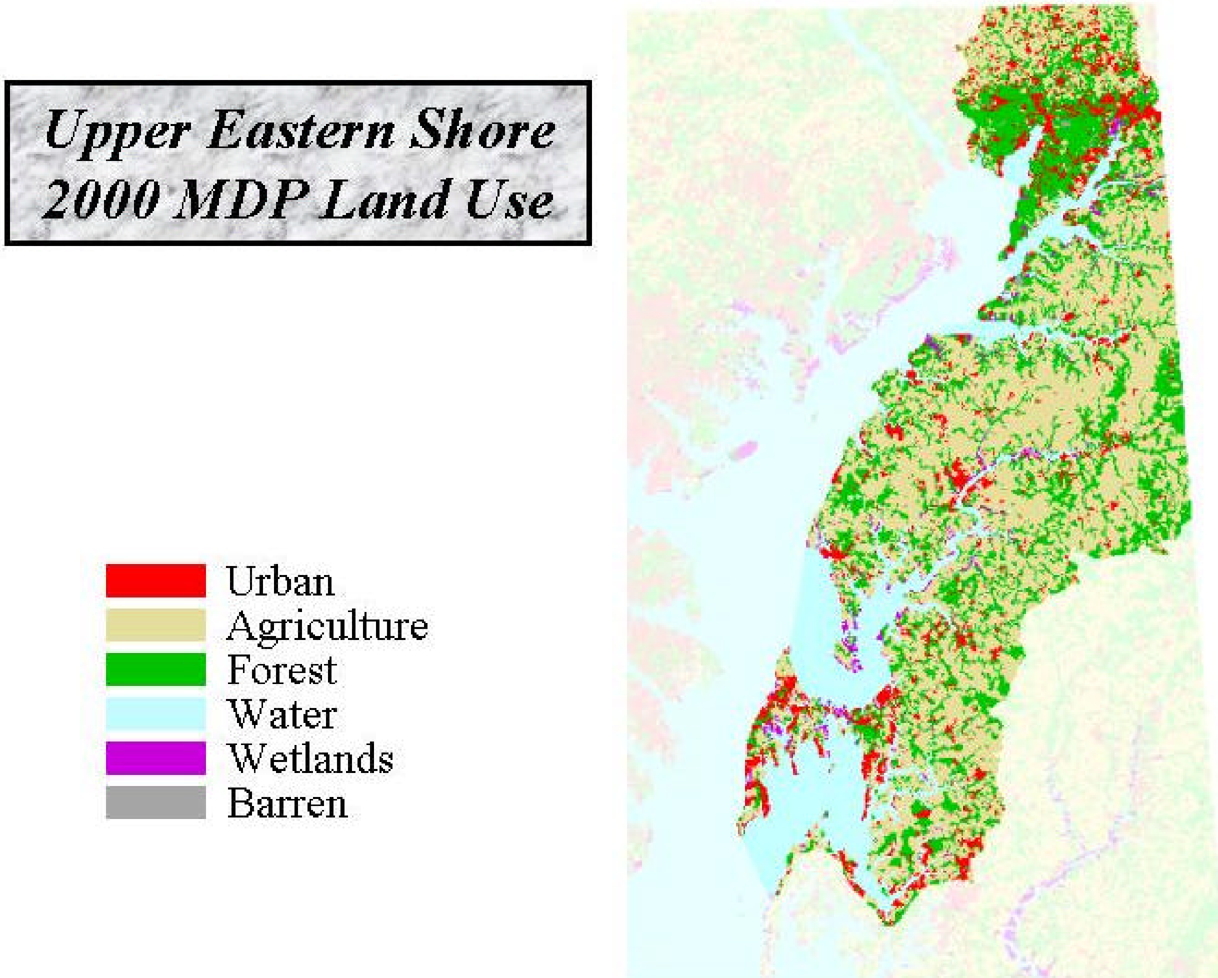


Figure UES3 – Wastewater Treatment Plants in the Upper Eastern Shore Basin

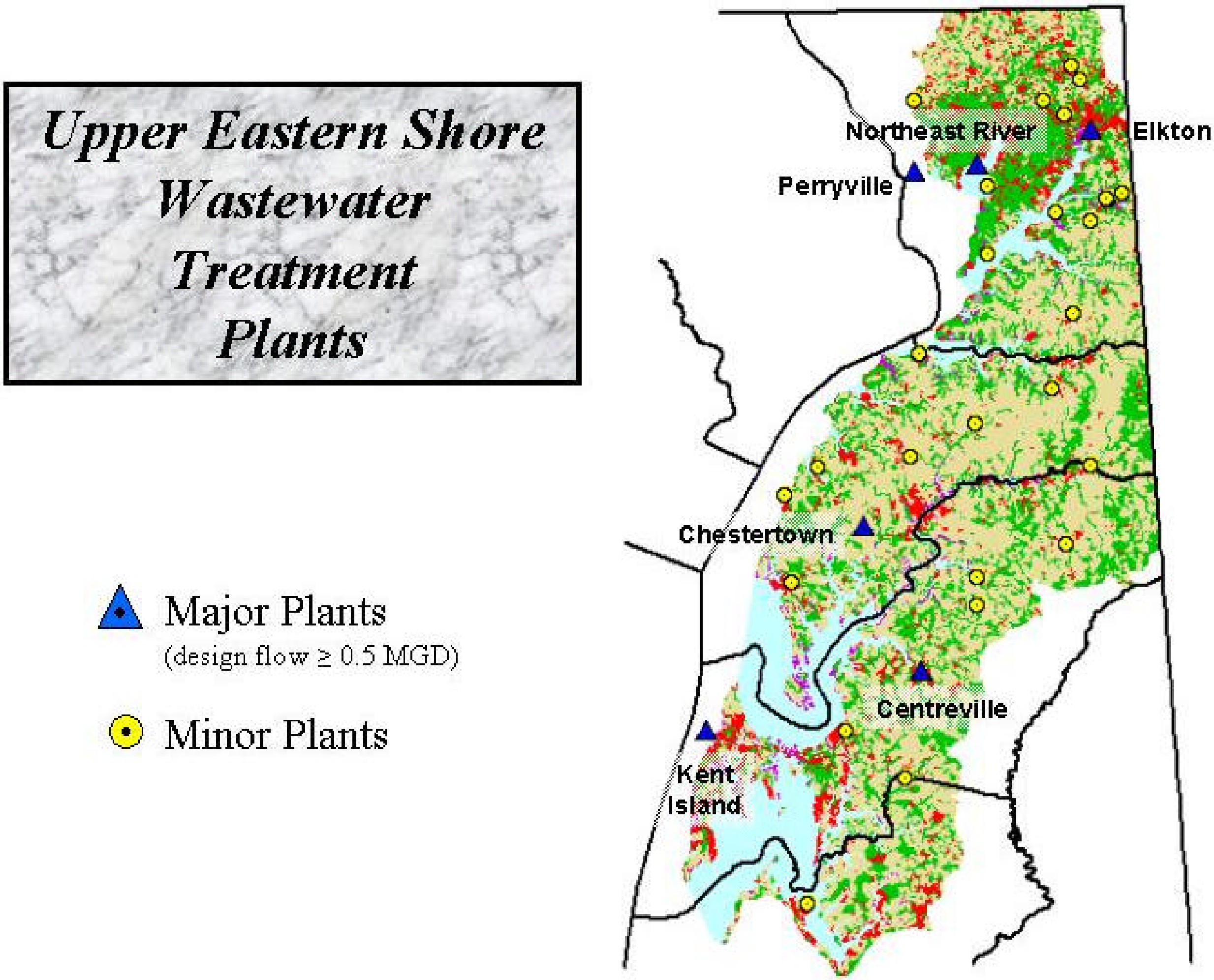


Figure UES4 – 1985 Nitrogen Contribution to the Upper Eastern Shore by source.

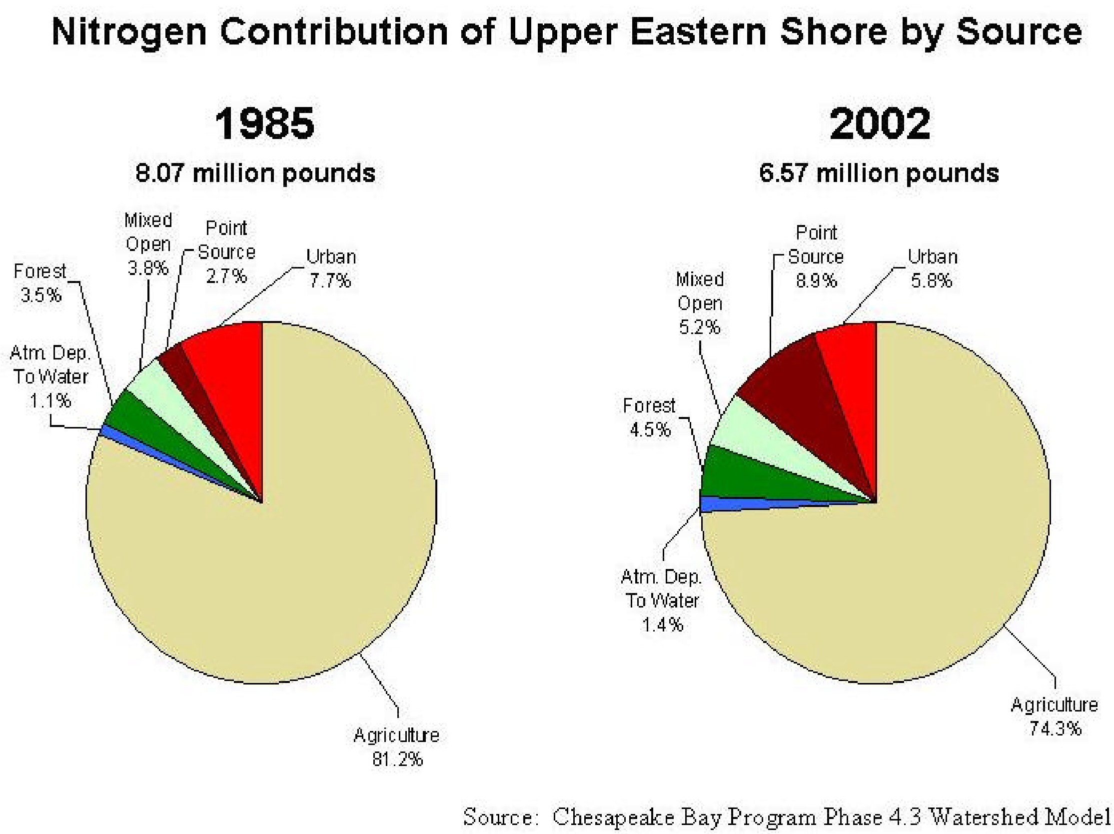


Figure UES5 – 1985 Phosphorus Contribution to the Upper Eastern Shore by source.

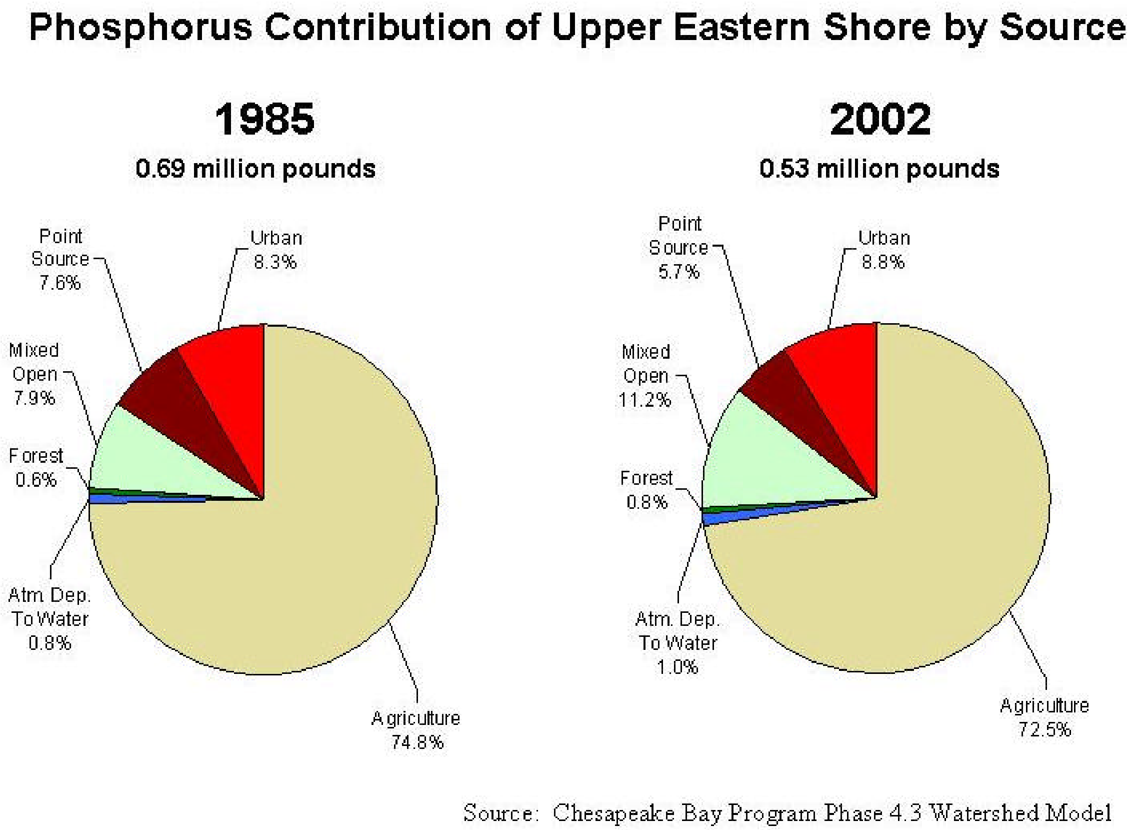
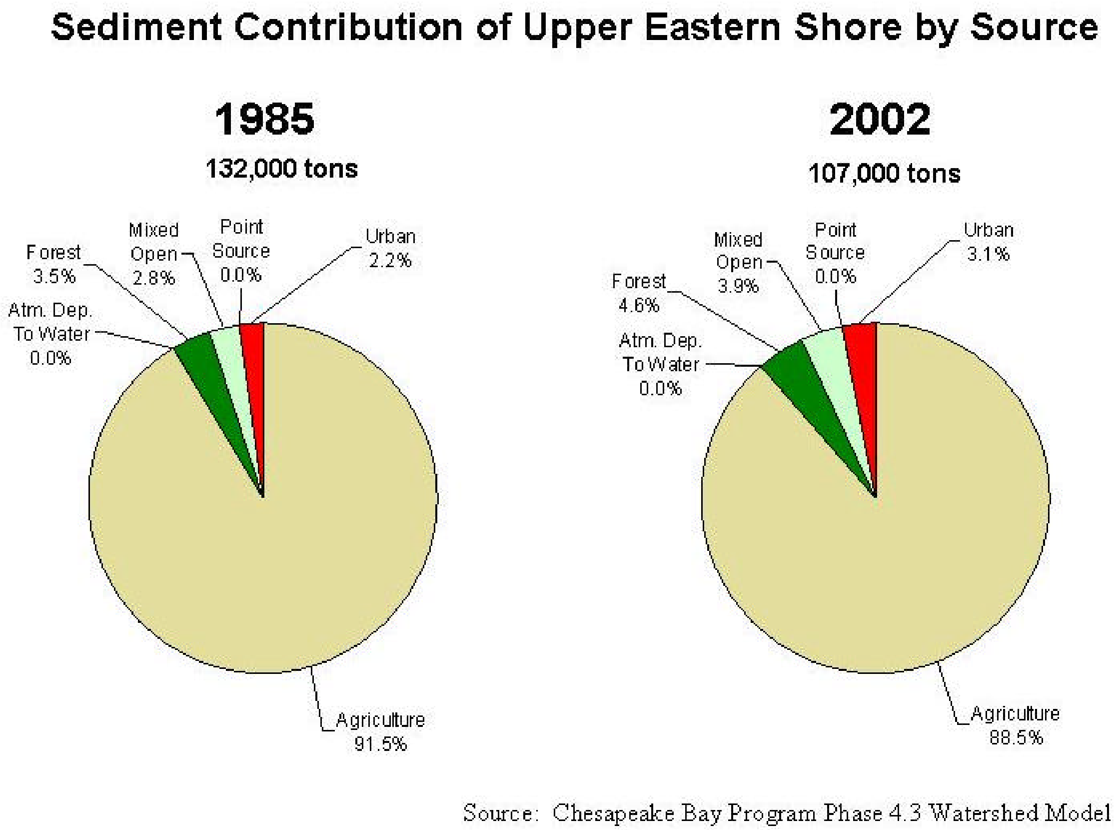


Figure UES6 – 1985 Sediment Contribution to the Upper Eastern Shore by source.



Overview of Monitoring Results

Water and Habitat Quality

Non-tidal Water Quality Monitoring Information Sources

Much useful information on non-tidal water quality is available on the Internet. The State of Maryland's Biological Stream Survey (MBSS) basin fact sheets and basin summaries are available at: **http://www.dnr.state.md.us/streams/mbss/mbss_fs_table.html** MBSS also reports stream quality information summarized by county at: **http://www.dnr.state.md.us/streams/mbss/county_pubs.html** In addition to these reports and fact sheets, detailed and more recent information and data are also available on the MBSS website: **http://www.dnr.state.md.us/streams/mbss**

Water quality information collected by Maryland's volunteer Stream Waders is available at: **http://www.dnr.state.md.us/streams/mbss/mbss_volun.html**

Long-term Water Quality Monitoring

Good water quality is essential to support the animals and plants that live or feed in the Upper Eastern Shore tributaries. Important water quality parameters are measured at eight long-term tidal monitoring stations in the Upper Eastern Shore, including nutrients, algal abundance, total suspended solids, water clarity (Secchi depth), and dissolved oxygen.

Current status is determined based on the most recent three-year period (2000-2002). For dissolved oxygen, the current concentrations are compared to ecologically meaningful thresholds to assign a status of good, fair, or poor. Thresholds have not been established for the other parameters, so the current data are compared to a baseline data set, and assigned a status of good, fair, or poor, which is only a *relative* status compared to the baseline data. Trends are determined using a non-parametric test for trend (the Seasonal Kendall test). For a detailed description of the methods used to determine status and trends, see http://www.dnr.state.md.us/bay/tribstrat/status_trends_methods.html.

Nutrients have decreased in some areas of the upper watershed. Nitrogen concentrations are relatively fair or poor at most stations. Phosphorus concentrations are better, and are relatively good at many stations. Nonetheless algal levels are relatively poor throughout much of the basin and are worsening at some stations. Total suspended solids have improved and are good to fair at all stations except the Upper Chester, which shows a poor status for five of the six parameters. Water clarity has improved at the Upper Chester station but worsened at the Lower Chester and Eastern Bay stations. Dissolved oxygen concentrations are good in the upper basin stations, but poor in the Lower Chester River and Eastern Bay stations.

Figure UES7 – Total Nitrogen Concentrations in the Upper Eastern Shore Basin

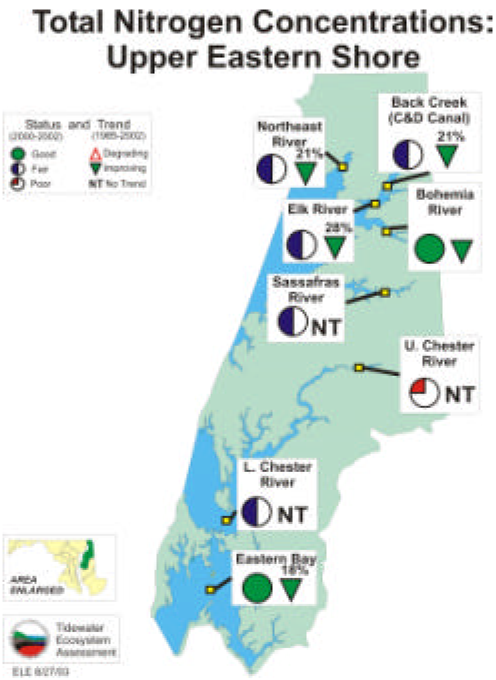


Figure UES8 – Total Phosphorus Concentrations in the Upper Eastern Shore Basin

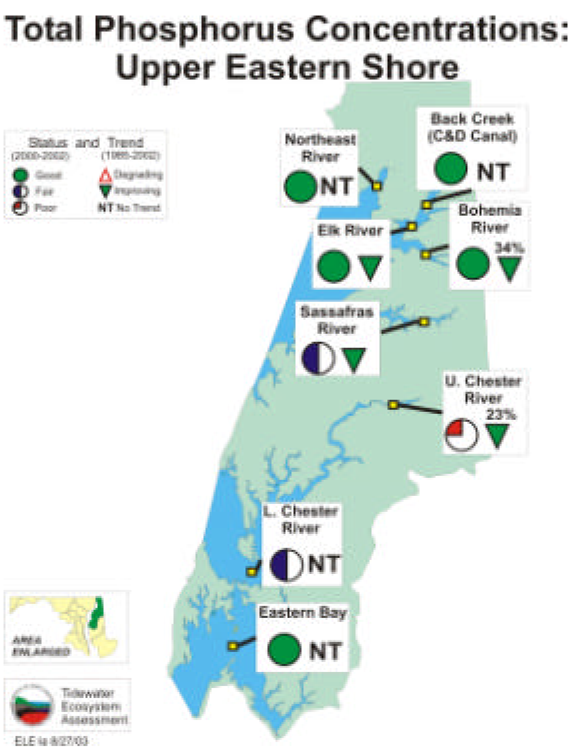


Figure UES9 – Abundance of Algae in the Upper Eastern Shore Basin

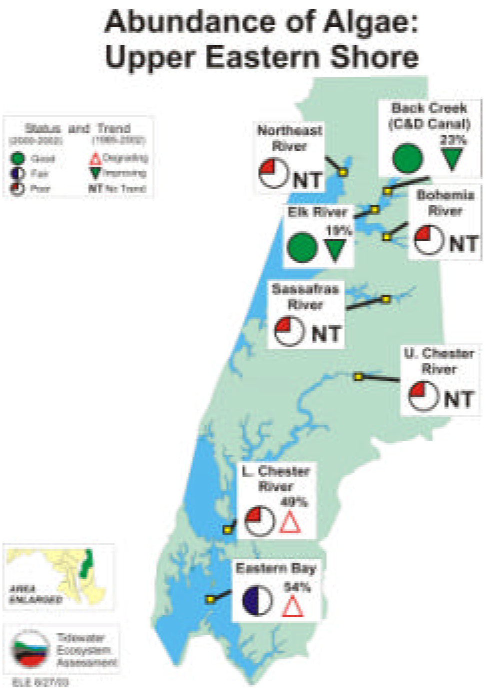


Figure UES10 – Total Suspended Solids Concentrations in the Upper Eastern Shore Basin

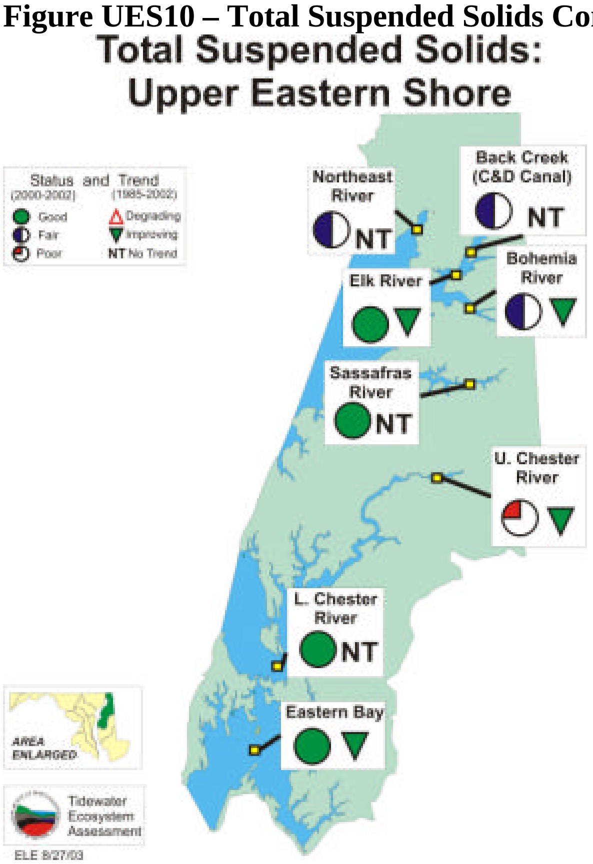
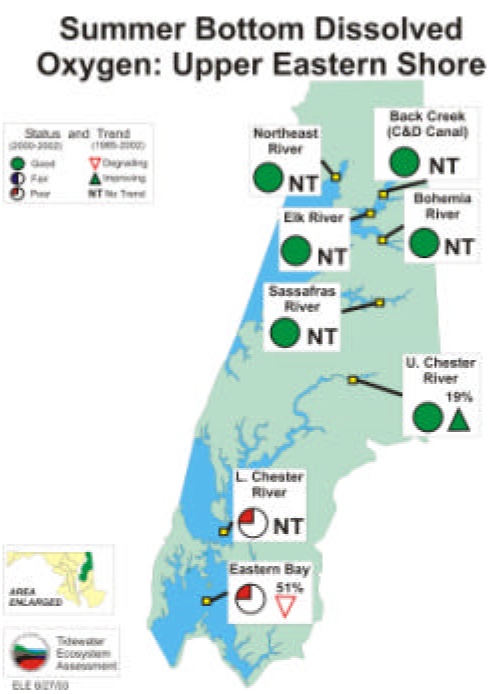


Figure UES11 – Water Clarity (Secchi Depth) in the Upper Eastern Shore Basin

Figure UES12 – Dissolved Oxygen in the Upper Eastern Shore Basin



SAV

The well-defined linkage between water quality and submerged aquatic vegetation (SAV) distribution and abundance make SAV communities good barometers of the health of estuarine ecosystems. SAV is important not only as an indicator of water quality, but it is also a critical nursery habitat for many estuarine species. Blue crab post-larvae are 30 times more abundant in SAV beds than adjacent unvegetated areas. Similarly, several species of waterfowl are dependant on SAV as food when they over-winter in the Chesapeake region.

The Chesapeake Bay Program has developed new criteria for determining SAV habitat suitability of an area based on water quality. The APercent Light at Leaf@ habitat requirement assesses the amount of available light reaching the leaf surface of SAV after being attenuated in the water column and by epiphytic growth on the leaves themselves. The document describing this new model is found on the Chesapeake Bay Program website (www.chesapeakebay.net/pubs/sav/index.html). The older AHabitat Requirements@ of five water quality parameters are still used for diagnostic purposes. Re-establishment of SAV is measured against the ATier 1 Goal@, an effort to restore SAV to any areas known to contain SAV from 1971 to 1990.

The tidal fresh Northeast River has had either no SAV or only small amounts since 1984 (Figure UES13), and a low Tier I goal (19 acres) (www.vims.edu/bio/sav/). However, after several years of no SAV being mapped, 1994 had 20 acres, surpassing the Tier I goal. Since then, the SAV coverage has been highly variable, fluctuating between 12 and 25 acres. In 2001, no SAV beds were identified. When present, beds are usually located in the vicinity of Carpenter Point and Cara Cove. Ground-truthing by citizens and staff from Harford County College have found, in order of frequency, milfoil, wild celery, coontail, hydrilla, water stargrass, naiads and horned pondweed. Water quality data from the station located near Charlestown indicate that phosphorous levels meet and percent light at leaf, light attenuation, and concentrations of algae and suspended solids fail the SAV habitat requirements. Nitrogen levels are not applicable in this tidal fresh environment with respect to SAV habitat requirements.

In 2001, Back Creek, at the mouth of the Chesapeake & Delaware Canal, had SAV identified (6.6 acres) for the first time since 1978 (www.vims.edu/bio/sav/) representing 440 percent of the Tier I goal of 1.5 acres (Figure UES13). There is no ground-truthing information for this segment. Water quality data from the station located near Chesapeake City indicate that only algae levels meet the SAV habitat requirements, and light attenuation and percent light at leaf are borderline. Suspended solid and phosphorous levels fail the requirements. Nitrogen is not applicable in this low salinity environment with respect to SAV habitat requirements.

The low salinity (oligohaline) Elk River has had highly variable SAV coverage since 1989 (Figure UES13), though there has been an increasing trend in SAV abundance since 1996 (which had 108 acres). In 2001, the increasing trend continued, with 2,035 acres of SAV being identified, which is the second year in a row that the Tier I goal of 1,105 acres has been exceeded (by 84 percent) in the aerial survey (www.vims.edu/bio/sav/). The SAV beds fringe much of the shoreline from Plum Point to Turkey Point on the northwestern side of the river, and the southeastern shore from just Paddy Biddle Cove to Worth Point. The most dramatic increases in 2001 occurred in Paddy Biddle Cove. Ground-truthing by citizens and staff from Harford Community College and EPA have found, in order of frequency of occurrence, milfoil, wild celery, sago pondweed, coontail, hydrilla, curly pondweed and water stargrass. Based on analysis of water quality data from the monitoring stations located near Oldfield Point, concentration of algae meet, while light attenuation and levels of suspended solids are borderline to the SAV habitat requirements. Phosphorous concentrations and percent light at leaf fail the requirements. Nitrogen levels are not applicable in this low salinity area with respect to SAV habitat requirements.

In the low salinity (oligohaline) Bohemia River, there has been a relatively steady increase in SAV coverage (www.vims.edu/bio/sav/) since a low of less than an acre in 1993. There was an astounding increase in SAV in 2001 to 354 acres, or 828 percent of the Tier I goal of 43 acres and this also represents an 89 percent increase from 2000 (Figure UES13). SAV fringes most of the shoreline from the Route 213 bridge to the mouth of the river. The largest increases seen in SAV coverage occurred from Battery Point (south shore) and Rich Point (on the north shore) to the Route 213 bridge. Limited ground-truthing by citizens and staff from Harford Community College have found in order of frequency; milfoil, wild celery, hydrilla, coontail and curly pondweed. Water quality data from the station near Old Hack Point indicate that only phosphorous levels meet the SAV habitat requirements, while percent light at leaf, light attenuation, algae and suspended solids concentrations fail. Nitrogen is not applicable in this low salinity river with respect to SAV habitat requirements.

The low salinity (oligohaline) Sassafras River has had highly variable SAV coverage since 1984 (www.vims.edu/bio/sav/), with a low of 34 acres in 1992 and a high of 1,169 acres in 2001 (287 percent of the Tier I goal of 407 acres) (Figure UES13). The largest SAV beds are located on the southern (Kent County) shore of the river, in Freeman, Turner and Lloyd Creeks, with fringing beds lining the river from Shrewsbury Neck to the mouth, though isolated beds exist as far upstream as Island Creek. Beds on the northern (Cecil County) shore are in Money Creek and fringing the shoreline from Grove Point and upstream to Foreman Creek. Ground-truthing by staff from Harford Community College has found, in order of frequency observed, milfoil, wild celery, coontail, hydrilla, sago pondweed, naiads and water stargrass. The Department of Natural Resources has been removing the invasive floating plant, water chestnut from several creeks in the Sassafras area. Water chestnut is an exotic species that can out compete native submerged species. The spiked seeds of this plant can also pose a hazard to people swimming or water skiing in the area (http://www.dnr.state.md.us/bay/sav/water_chestnut.html). Water quality data from the station located at the Route 213 bridge near Georgetown indicate that only phosphorous levels meet the SAV habitat requirements, while the other four (percent light at leaf, light attenuation, suspended solids and algae concentrations) fail. Nitrogen is not applicable in this low salinity river with respect to SAV habitat requirements.

In the tidal fresh and low salinity (oligohaline) Chester River, SAV has never been mapped (www.vims.edu/bio/sav/) (Figure UES13). There is no Tier I goal, and the area has never been ground-truthed. There is no water quality data for the low salinity (oligohaline) region. Data for the tidal fresh area, obtained from the station located near Crumpton indicate that only phosphorous levels meet the SAV habitat requirements, while the other four (percent light at leaf, light attenuation, suspended solids and algae concentrations) fail. Nitrogen is not applicable in this low salinity river with respect to SAV habitat requirements.

In the moderate salinity (mesohaline) portion of Chester River, SAV coverage has been highly variable since 1984 (Figure UES13), ranging from a low of 80 acres in 1990 to a high of 1,181 acres in 1998 (www.vims.edu/bio/sav). SAV coverage declined in both 1999 and 2000. The 1999 decline was due to the elevated Summer salinities resulting from drought conditions. These higher than normal salinities produced conditions beyond the local species salinity tolerances. In 2000, large, dense algal blooms greatly reduced available light needed by SAV during the critical Spring growing period. In 2001, SAV recovered slightly, reaching 206 acres or about 5 percent of the Tier I goal of 3751 acres. In 2001 SAV was found primarily on the Queen Anne's County side of the river from Kent Narrows to Abbot Cove with the largest beds on both sides of the mouth of Queenstown Creek. Ground-truthing by citizens (and the Chester River Association) and staff from Maryland DNR, Patuxent River Wildlife Center, U. S. Fish and Wildlife Service and Environmental Protection Agency has found, in order of most frequently reported, redhead grass, milfoil, elodea, widgeon grass, sago pondweed, horned pondweed, wild celery and naiads. Water quality monitoring data from the station located between the southern tip of Eastern Neck Island and Kent Narrows indicate that suspended solids and phosphorous level meet the SAV habitat requirements, while light attenuation, percent light at leaf and levels of nitrogen and algae are borderline.

In the moderate salinity (mesohaline) Eastern Bay, SAV coverage has been increasing since 1991 (Figure UES13), ranging from a low of 168 acres in 1991 to a high of 4,955 acres in 1999 (www.vims.edu/bio/sav/), which represented 81 percent of the Tier I goal (6126). Due to large, dense algal blooms reducing the amount of available light in Spring of 2000, SAV coverage declined dramatically. Fortunately, 2001 SAV coverage rebounded well, reaching 2,887 acres (47 percent of Tier I). Typically there are large beds on most shorelines around Eastern Bay and Miles River and smaller more scattered beds in the Wye River. Ground-truthing by citizens and staff from Maryland DNR, Patuxent River Wildlife Center, U. S. Fish and Wildlife Service, U. S. Geological Survey, National Aquarium in Baltimore, National Oceanic and Atmospheric Administration and Virginia Institute of Marine Science has found, in order of most frequently reported, widgeon grass, horned pondweed, redhead grass, milfoil, sago pondweed, elodea, eel grass and naiads. Water quality monitoring data from the station located between the southern tip of Parson's Island and Tilghman Point indicate that percent light at leaf, light attenuation, suspended solids, algae and phosphorous level meet the SAV habitat requirements, while levels of nitrogen are borderline.

Figure UES13 – Submerged Aquatic Vegetation in the Upper Eastern Shore Basin

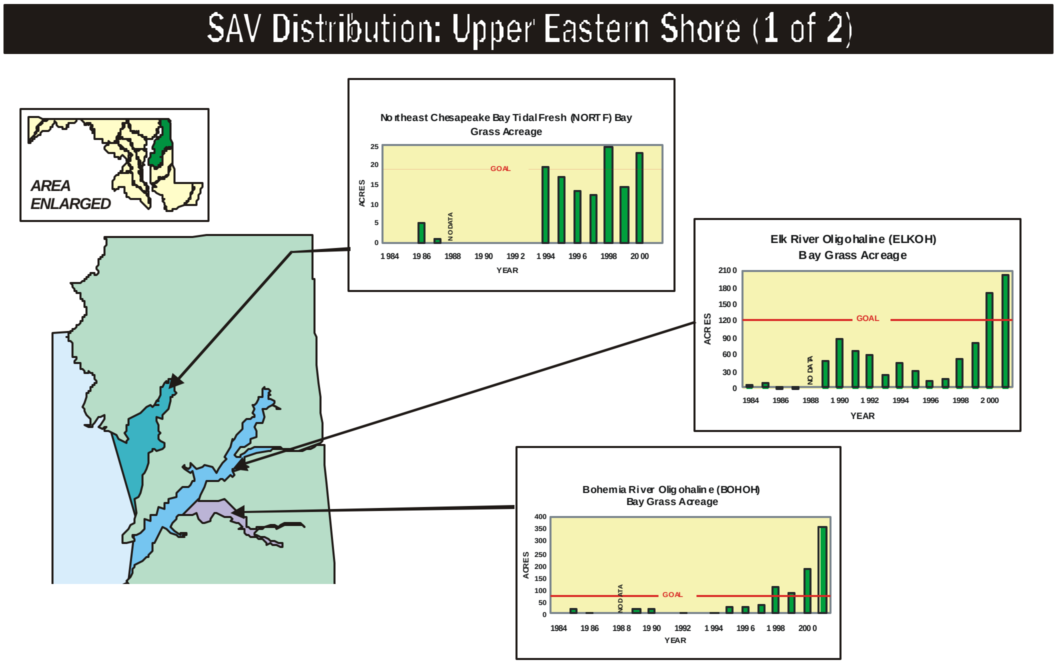


Figure 1a: SAV coverage on the Upper Eastern Shore, 1984 to 2001

SAV Distribution: Upper Eastern Shore (2 of 2)

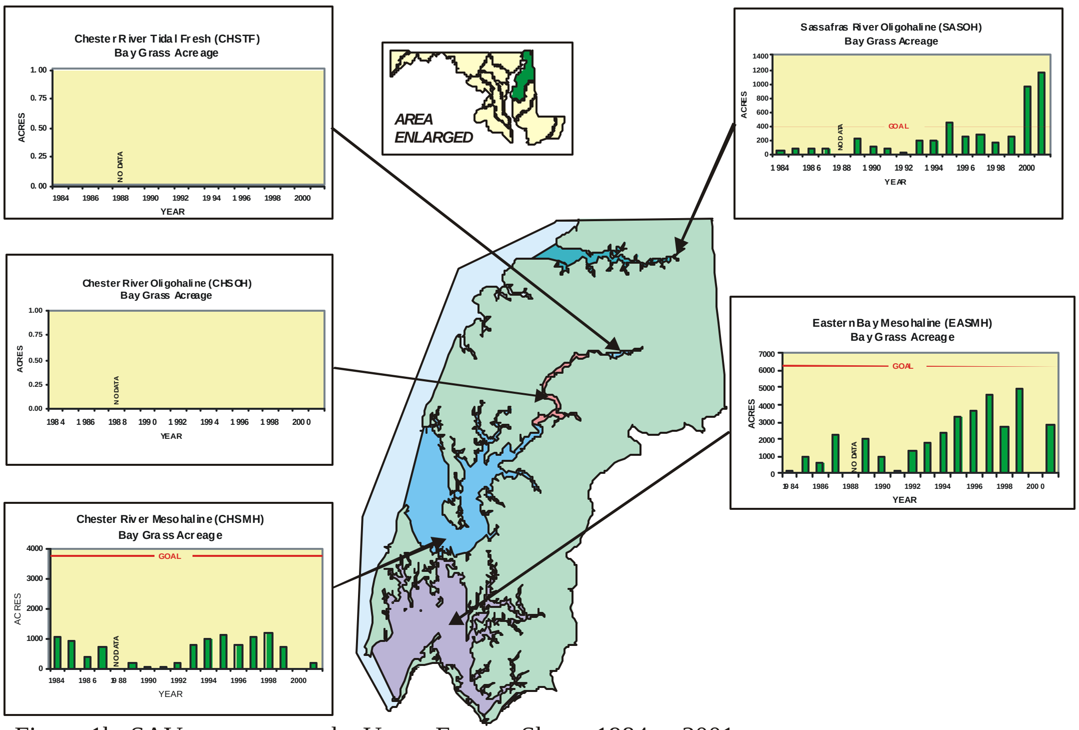


Figure 1b: SAV coverage on the Upper Eastern Shore, 1984 to 2001

Benthic Community

The benthic community forms an integral part of the ecosystem in estuarine systems. For example, small worms and crustaceans are key food items for crabs and demersal fish, such as spot and croaker. Suspension feeders that live in the sediments, such as clams, can be extremely important in removing excess algae from the water column. Benthic macroinvertebrates are reliable and sensitive indicators of estuarine habitat quality.

Benthic monitoring includes both probability-based sampling (sampling sites are selected at random) and fixed station sampling (the same site is sampled every year). A benthic index of biotic integrity (B-IBI) is determined for each site (based on abundance, species diversity, etc.). The B-IBI serves as a single-number indicator of benthic community health. For a more details on the methods used in the benthic monitoring program see http://esm.versar.com/Vcb/Benthos/backgrou.htm

During the period 1994-2000, the Northeast River, Bohemia River, and Eastern Bay were in worst condition, with a probability of observing degraded benthos of over 50 percent with good confidence (Figure UES14). Benthic community condition in the Elk and Sassafras Rivers was largely indeterminate, but not severely degraded. The Chester River oligohaline and tidal freshwater regions showed a greater than 50 percent probability of degraded benthos, but there was less than 67 percent confidence in this estimate. Very few samples were collected in the Northeast and Bohemia Rivers, and in the oligohaline and tidal freshwater portions of the Chester River, so results for these basin segments should be viewed with caution.

The Chester River mesohaline region showed a relatively high probability of degraded benthos (45 percent, Figure UES14), but most sites with failing B-IBI were concentrated in the lower portion of the estuary, around Eastern Neck Island. Poor benthic community condition in this region could not be attributed to stress from low dissolved oxygen. However, 34 percent of all mesohaline segment sites in the Chester River exhibited excess abundance of organisms, suggesting organic enrichment conditions consistent with degrading trends in water quality parameters.

There were no significant trends in the B-IBI at the fixed long-term benthic monitoring stations in the Elk (Station 29) and Chester (Station 68) Rivers (Figure UES15). The current benthic community status at the Elk River station (marginally degraded) agrees well with a general condition for the river that is neither severely degraded nor good. A significant decrease in the abundance of species indicative of pollution, however, suggests some improvement in benthic condition, which is consistent with observed improving trends in water quality parameters.

The current status for the Chester River fixed station is good (meets goal), but this station is located mid-river above the region where a majority of the random sites failed the B-IBI. In the past, high densities of organisms at this station suggested organic enrichment; now, abundance values have decreased indicating significant improvement.

Figure UES14- Number of sites failing the B-IBI and probabilities (SE) of observing degraded benthos, non-degraded benthos, or benthos of intermediate condition (indeterminate for low salinity habitats) for Maryland Upper Eastern Shore Basin tributaries, 1994-2000. See Table 1 for additional information. Segment codes: TF= tidal freshwater, OH = oligohaline, MH =mesohaline.

Segment	Tributary	Number of Sites	Sites with B-IBI<3.0	P Deg.	P Non-deg.	P Interm.
NORTF	Northeast	5	4	66.7 (15.7)	22.2 (13.9)	33.3 (15.7)
ELKOH	Elk	10	4	28.6 (12.1)	28.6 (12.1)	57.1 (13.2)
BOHOH	Bohemia	2	2	66.7 -	33.3 -	33.3 -
SASOH	Sassafras	11	3	33.3 (12.2)	13.3 (8.8)	66.7 (12.2)
CHSTF	Chester	1	1	60.0 -	40.0 -	40.0 -
CHSOH	Chester	4	2	50.0 -	37.5 -	37.5 -
CHSMH	Chester	38	18	45.2 (7.7)	33.3 (7.3)	26.2 (6.8)
EASMH	Eastern Bay	12	9	68.8 (11.6)	25.0 (10.8)	18.8 (9.8)

Figure UES15 - Trends in benthic community condition at Maryland Upper Eastern Shore Basin long-term monitoring stations, 1985-2000. Trends were identified using the van Belle and Hughes (1984) procedure. Current mean B-IBI and condition are based on 1998-2000 values. Initial mean B-IBI and condition are based on 1985-1987 values. NS: not significant.

Station[1]	Trend Significance	Median Slope (B-IBI units/yr)	Current Condition (1998-2000)	Initial Condition (1985-1987)
29 Elk	NS	0.00	2.78 (Marginal)	2.42 (Degraded)
68 Chester	NS	0.00	3.56 (Meets Goal)	3.51 (Meets Goal)

[1]Sta. 29 Elk River, oligohaline habitat, 39.479615 lat., 75.944499 long.
Sta. 68 Chester River, low mesohaline habitat, 39.132941 lat., 76.078679 long.

Nutrient Limitation

Like all plants, phytoplankton need nitrogen, phosphorus, light, and suitable water temperatures to grow. If light is adequate and the water temperature is appropriate, phytoplankton will continue to grow as long as unlimited amounts of nutrients are available. If nutrients are not unlimited, then the ratio of nitrogen to phosphorus affects phytoplankton growth. (Phytoplankton generally use nitrogen and phosphorus at a ratio of 16:1, that is, 16 times as much nitrogen is needed as phosphorus. This is called the Redfield ratio.) If one of the nutrients is not available in the adequate quantity, phytoplankton growth is ‘limited’ by that nutrient. If both nutrients are available in enough excess (regardless of the relative proportion of them) that the phytoplankton can not use them all even when they are growing as fast as they can under the existing temperature and light conditions, then the system is ‘nutrient saturated.’

Nitrogen limitation occurs when there is insufficient nitrogen, i.e., there is excess phosphorus. Nitrogen limitation often happens in the summer and fall after stormwater flows are lower (so less nitrogen is being added to the water) and some of the nitrogen has already been used up by phytoplankton growth during the spring. If an area is nitrogen limited, then adding nitrogen will increase phytoplankton growth.

Phosphorus limitation occurs when there is insufficient phosphorus, i.e. there is excess nitrogen. If an area is phosphorus limited, then adding phosphorus will increase phytoplankton growth. Phosphorus limitation occurs in some locations in the spring when large amounts of nitrogen are added to the estuary from stormwater flow.

If an area is nutrient saturated, then both nitrogen and phosphorus are available in excess. In this case, if phytoplankton are exposed to appropriate water temperatures and sufficient light, they will grow. If an area is both nitrogen and phosphorus limited, then both nitrogen and phosphorus must be added to increase algal growth.

Managers can use the nutrient limitation model to predict which nutrient is limiting at a given location and use the information to assess what management approach might be the most effective for controlling excess phytoplankton growth. If an area is phosphorus limited, then reducing phosphorus will bring the most immediate reductions in phytoplankton grown. However, if nitrogen levels are not also reduced, the excess nitrogen that goes unused can be exported downstream. This excess nitrogen may reach an area that is nitrogen limited, fueling phytoplankton growth in that downstream area.

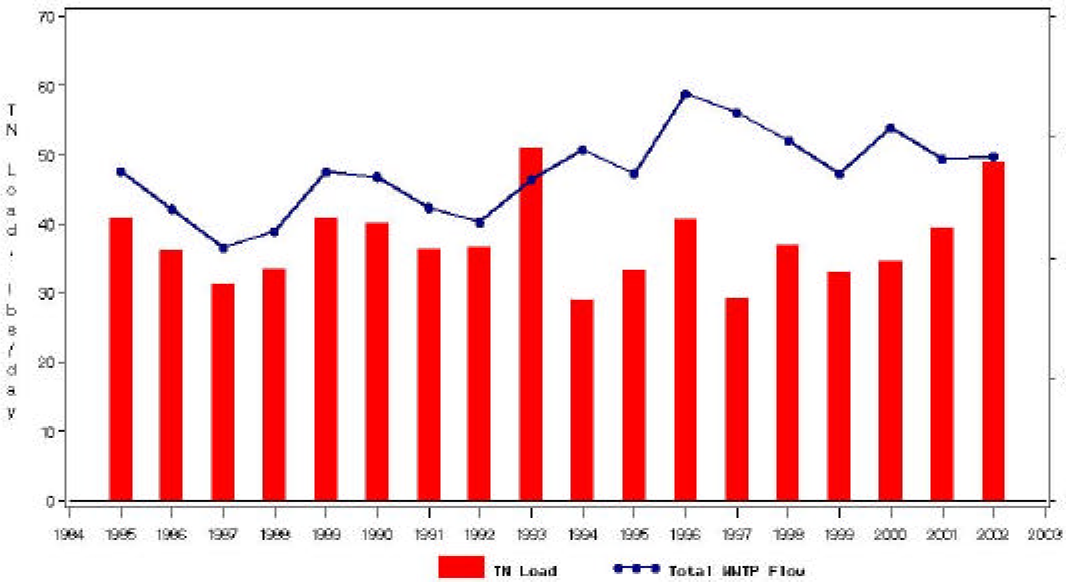
The nutrient limitation predictions are a valuable tool, but they must be used in conjunction with other water quality and watershed information to fully assess and evaluate the best management approach.

The nutrient limitation model was used to predict nutrient limitation for the ten stations in the Upper Eastern Shore. Results are summarized for the most recent three-year period (2000-2002) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). Managers can use these predictions to assess what management approach will be the most effective for controlling excess phytoplankton growth. Interpreting the results can be a little counter-intuitive, however. Remember that nitrogen limited means that *phosphorus* is in excess. Initially, it would seem that the best management strategy would be to reduce phosphorus inputs. However, it may actually be more cost effective to further reduce *nitrogen* inputs to increase the amount of 'unbalance' in the relative proportions of nutrients so that phytoplankton growth is even more limited. When used along with other information available from the water quality and watershed management programs, these predictions will allow managers to make more cost-effective management decisions.

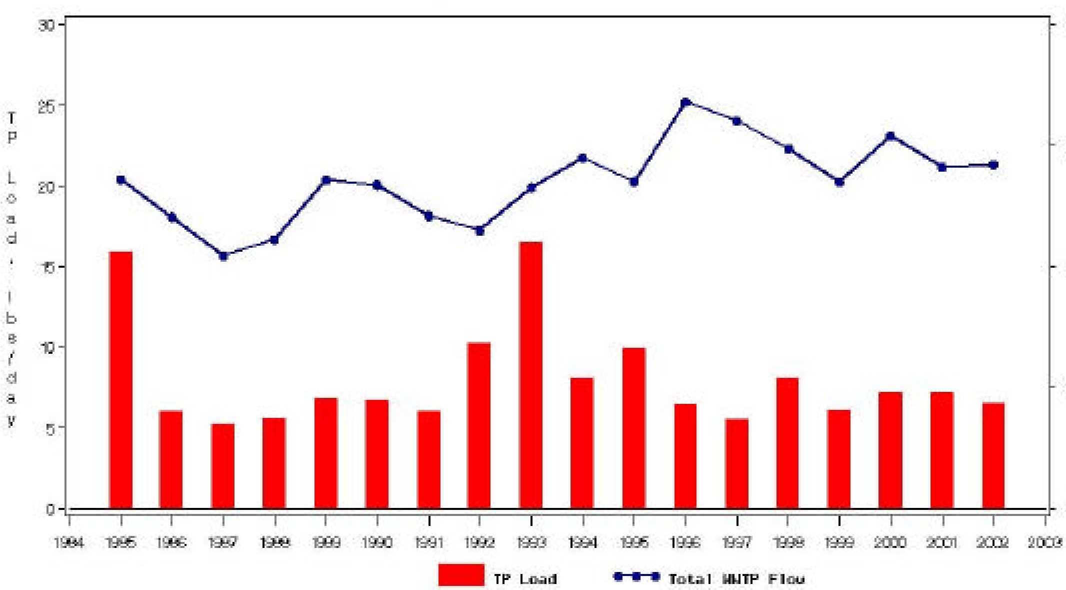
See Appendix B for details.

Appendix A – Nutrient Loads from Major Wastewater Treatment Facilities

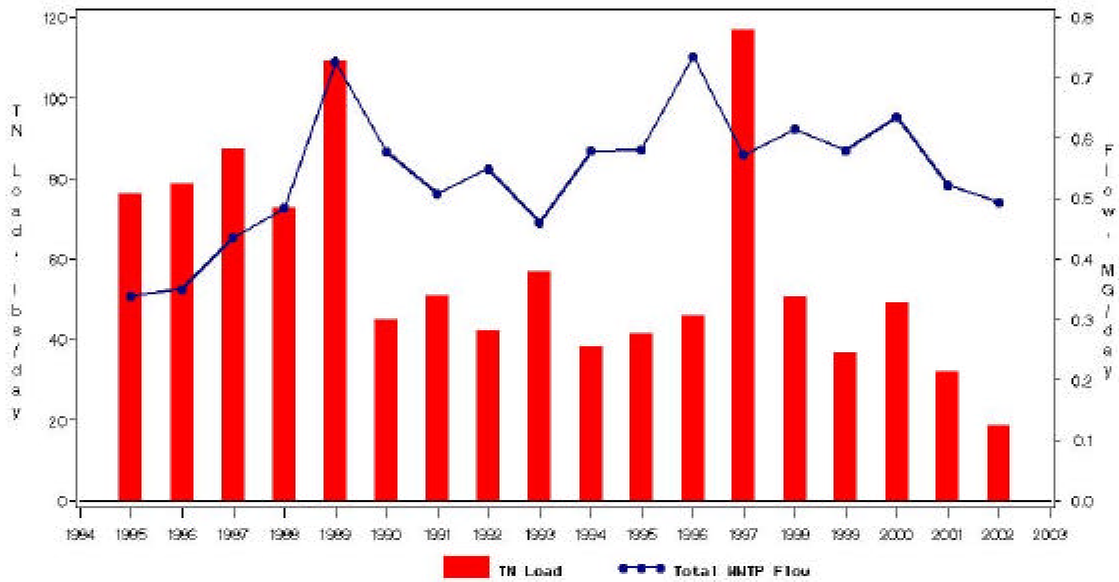
CENTREVILLE Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



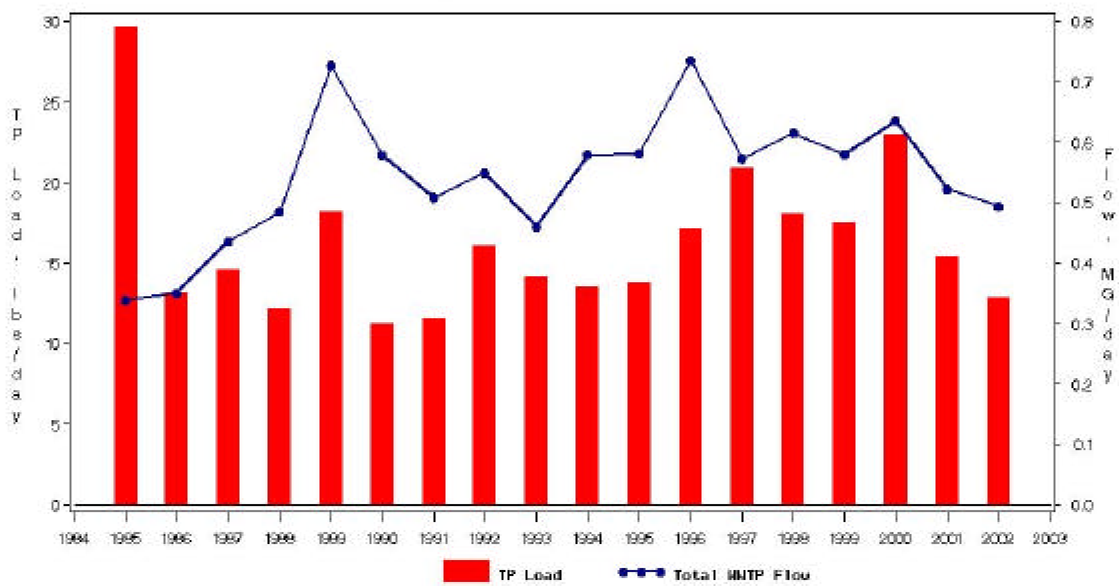
CENTREVILLE Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



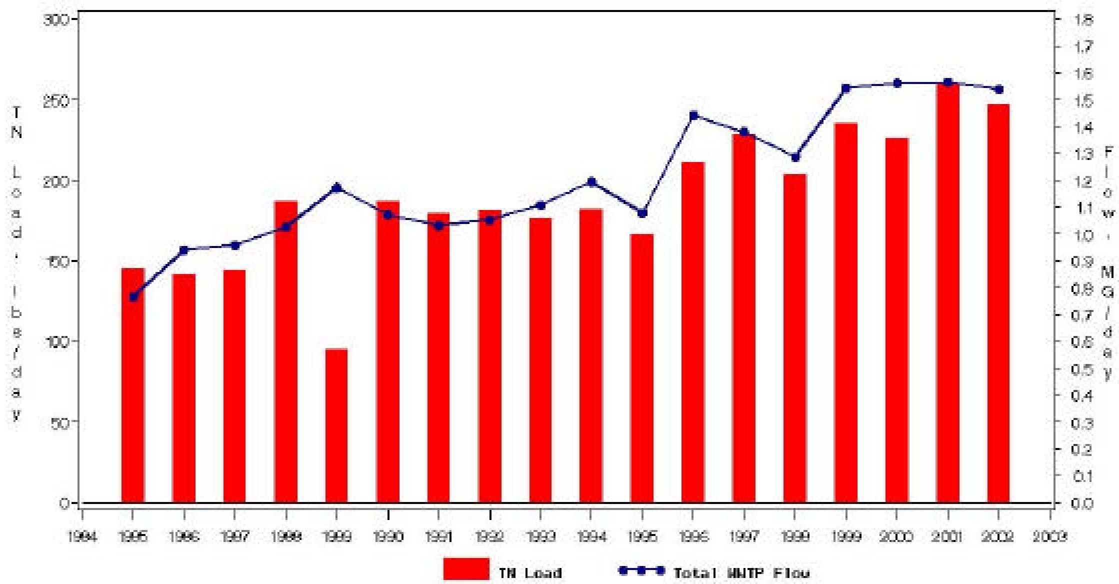
CHESTERTOWN Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



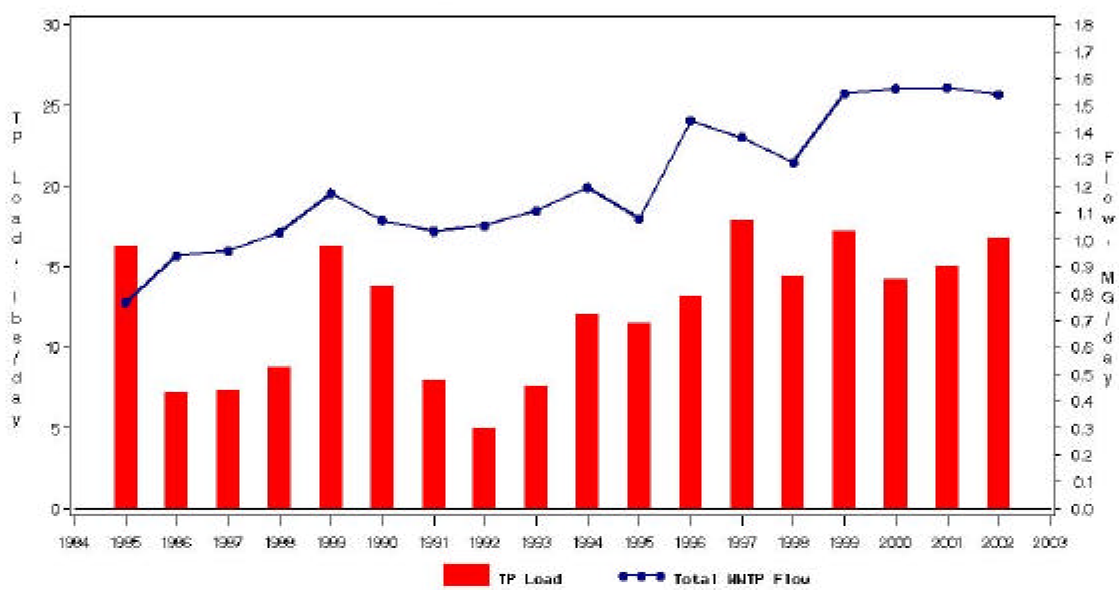
CHESTERTOWN Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



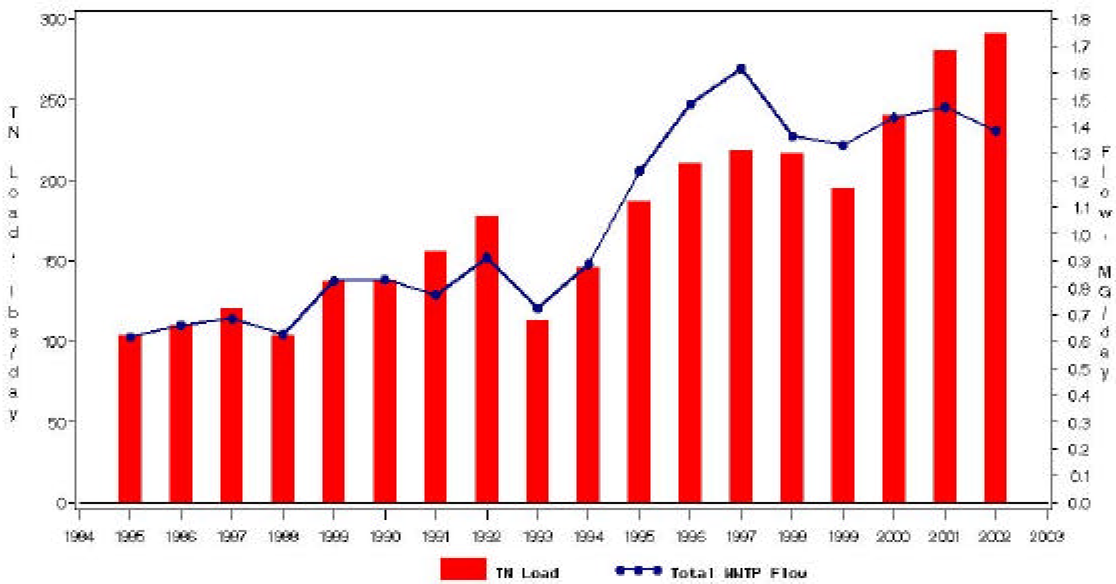
ELKTON Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



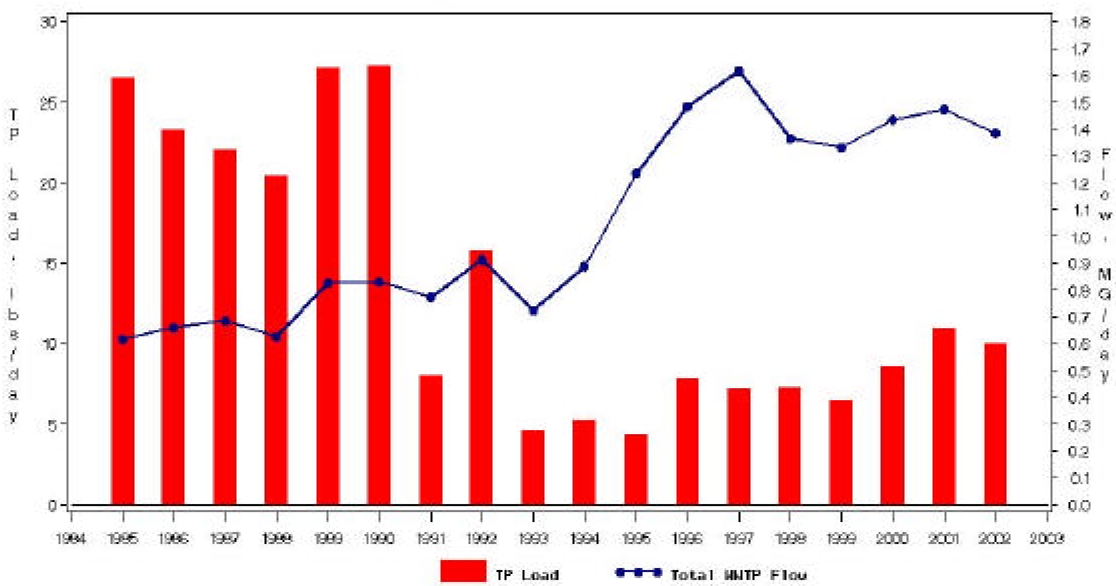
ELKTON Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



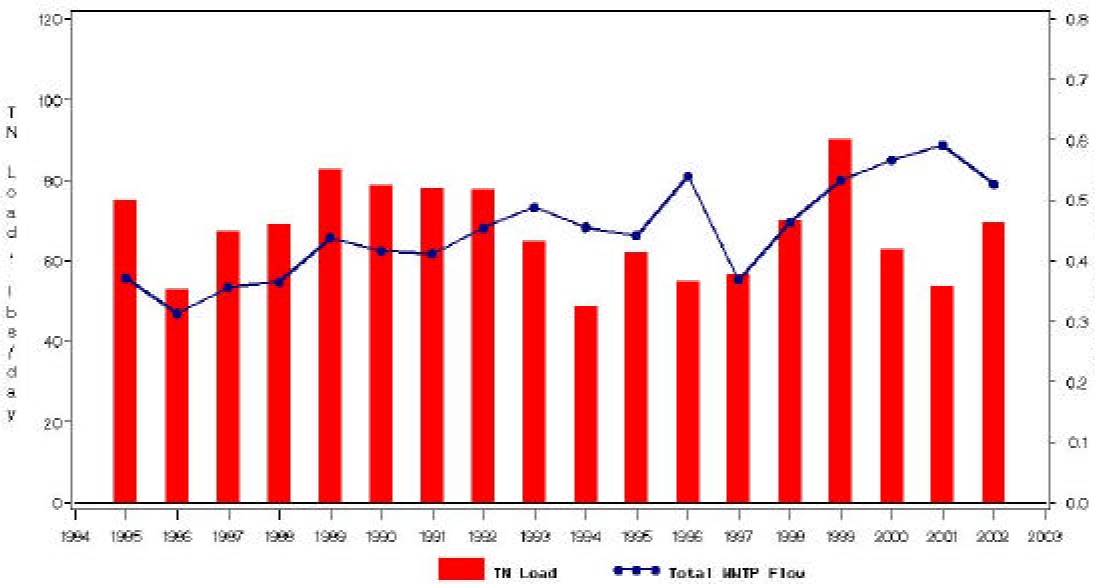
KENT ISLAND Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



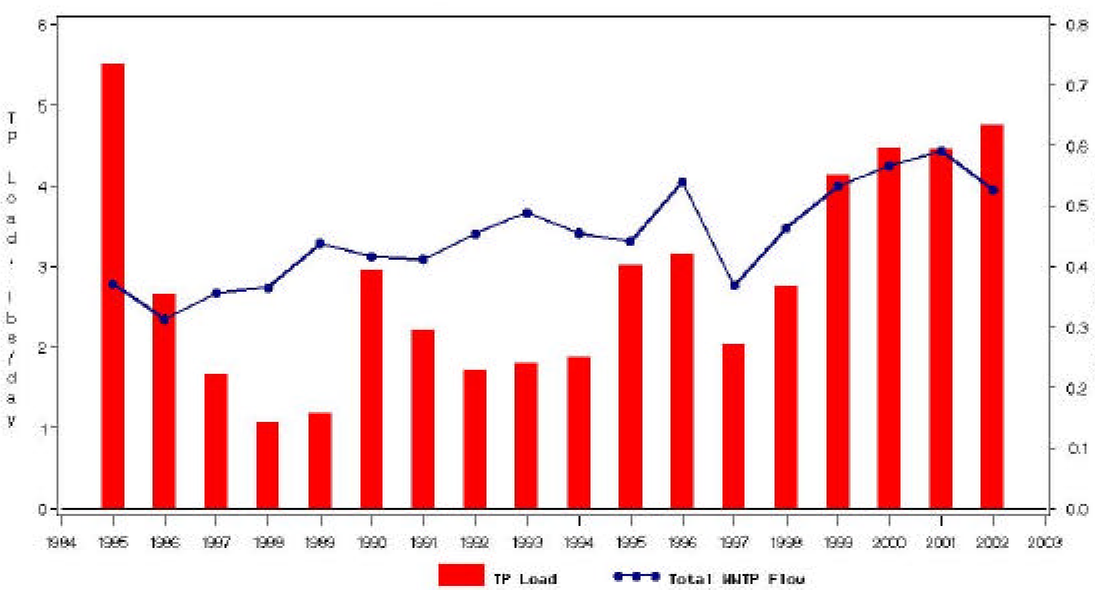
KENT ISLAND Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



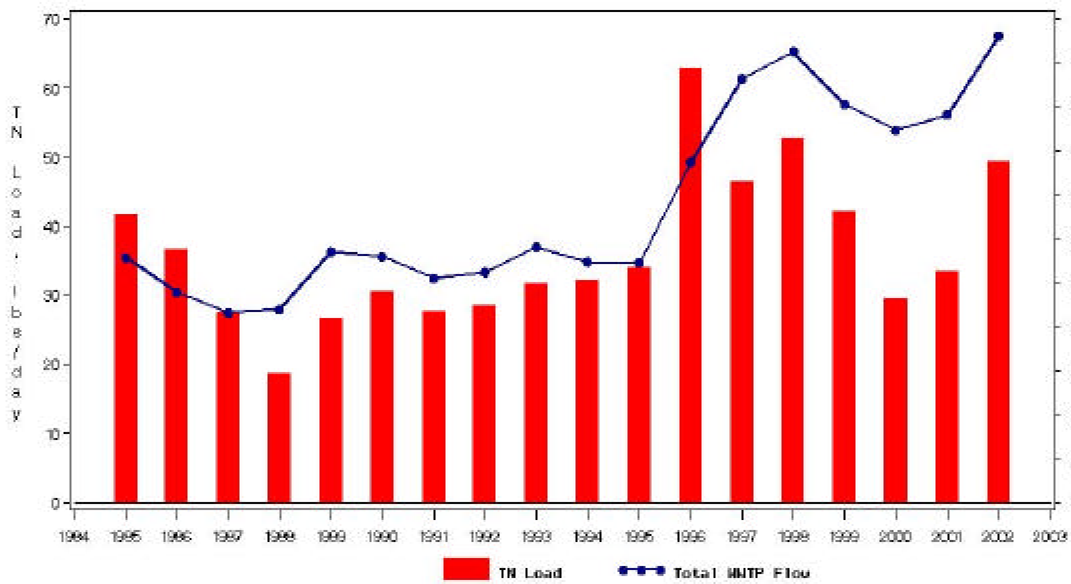
NORTHEAST RIVER Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



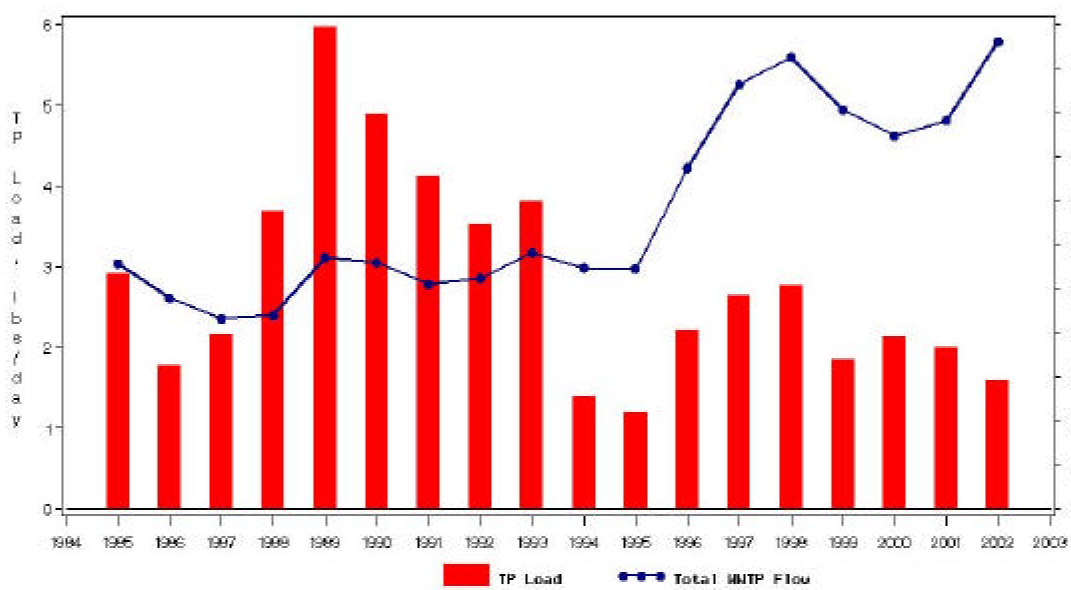
NORTHEAST RIVER Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow



PERRYVILLE Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Nitrogen Loads and Flow



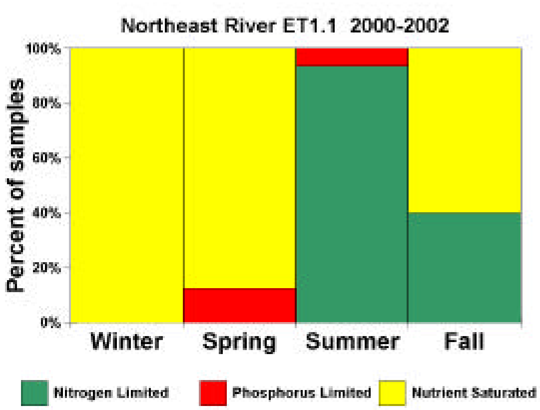
PERRYVILLE Wastewater Treatment Plant: Upper Eastern Shore Tributary Strategy Basin
Mean Daily Total Phosphorus Loads and Flow

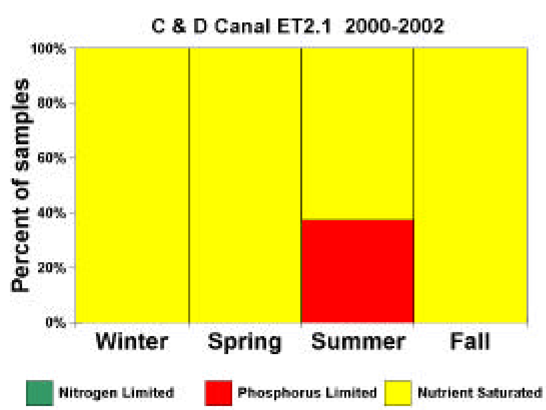


Appendix B – Nutrient Limitation Graphs for the Upper Eastern Shore Basin

The nutrient limitation model was used to predict nutrient limitation for the ten stations in the Upper Eastern Shore. Results are summarized for the most recent three-year period (2000-2002) by season: winter (December-February), spring (March-May), summer (July-September) and fall (October-November). Managers can use these predictions to assess what management approach will be the most effective for controlling excess phytoplankton growth. Interpreting the results can be a little counter-intuitive, however. Remember that nitrogen limited means that *phosphorus* is in excess. Initially, it would seem that the best management strategy would be to reduce phosphorus inputs. However, it may actually be more cost effective to further reduce *nitrogen* inputs to increase the amount of 'unbalance' in the relative proportions of nutrients so that phytoplankton growth is even more limited. When used along with other information available from the water quality and watershed management programs, these predictions will allow managers to make more cost-effective management decisions.

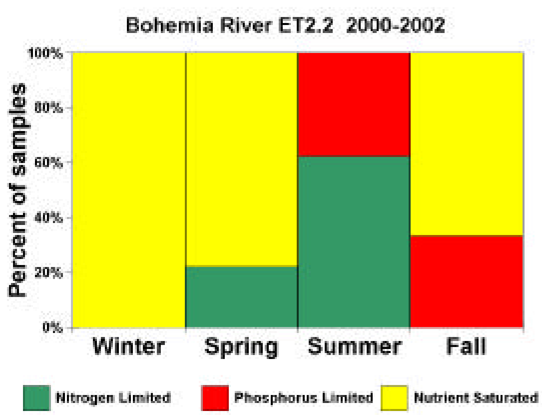
Northeast River (ET1.1)- On an annual basis, phytoplankton growth is nitrogen limited more than 35% of the time and phosphorus limited about 5% of the time. Winter growth is entirely nutrient saturated (light limitation or nutrient saturated). Spring growth is phosphorus limited more than 10% of the time and otherwise is nutrient saturated. Summer growth is nitrogen limited almost 95% of the time and phosphorus limited for the remainder. Fall growth is nitrogen limited 40% of the time and otherwise is nutrient saturated. Total nitrogen concentration is relatively fair and dissolved inorganic nitrogen concentration is relatively good and improving (decreasing); total and dissolved inorganic phosphorus concentrations are relatively good. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively high, indicating that additional phosphorus limitation could occur in the winter and spring. Reductions in nitrogen concentrations would also further limit growth in the summer and fall.

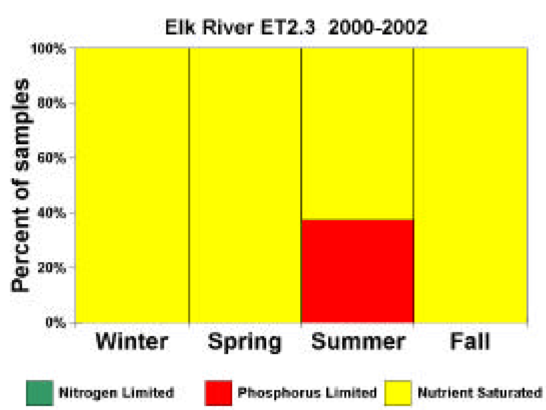




C & D Canal (ET2.1) – On an annual basis, phytoplankton growth is phosphorus limited 10% of the time, but occurs only in the summer (more than 35% of the summer samples); otherwise growth is nutrient saturated (light limited or no limitation). Total nitrogen concentration is relatively fair but dissolved inorganic nitrogen concentration is relatively poor; both are improving (decreasing). Total phosphorus concentration is relatively good, but dissolved inorganic phosphorus concentration is relatively poor and degrading (increasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is decreasing. Both nitrogen and phosphorus concentrations will need to be reduced before phytoplankton growth is limited in winter, spring and fall; decreases in phosphorus will further enhance phosphorus limitation in the summer.

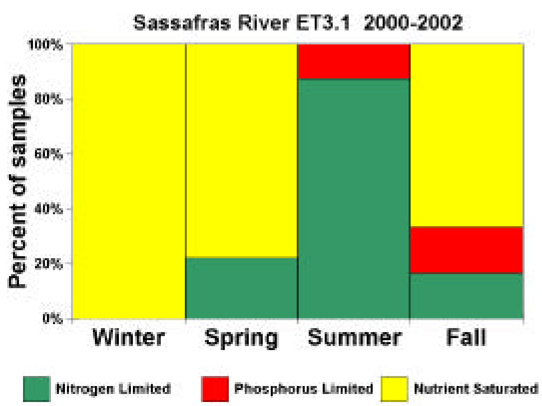
Bohemia River (ET2.2) – On an annual basis, phytoplankton growth is nitrogen limited approximately 25% of the time and phosphorus limited more than 15% of the time. In the winter, growth is always nutrient saturated (light limited or no limitation). In spring, growth is nitrogen limited more than 20% of the time otherwise is nutrient saturated. In the summer, growth is nitrogen limited more than 60% of the time and otherwise is phosphorus limited. Fall growth is phosphorus limited almost 35% of the time and is otherwise nutrient saturated. Total nitrogen, dissolved inorganic nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are all relatively good. Total nitrogen and total phosphorus concentrations are improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus suggests that reductions in phosphorus in winter and spring will increase phosphorus limitation in these seasons; reductions in nitrogen would further enhance nitrogen limitation in the summer.

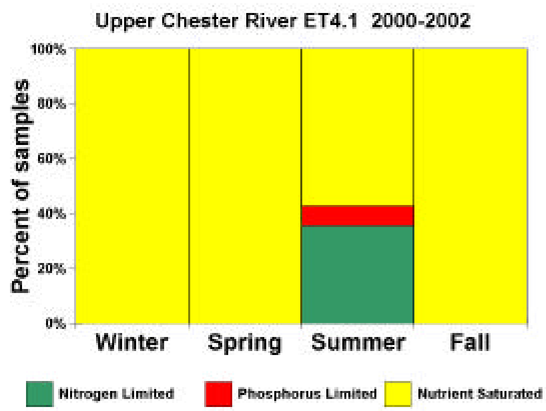




Elk River (ET2.3) – On an annual basis, phytoplankton growth is phosphorus limited 10% of the time, but this occurs only in the summer (more than 35% of the summer samples); otherwise growth is nutrient saturated (light limited or no limitation). Total nitrogen concentration is relatively fair but dissolved inorganic nitrogen concentration is relatively poor. Total phosphorus concentration is relatively good, but dissolved inorganic phosphorus concentration is relatively poor and degrading (increasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is decreasing; this ratio also suggests that further reductions in phosphorus concentration are needed to allow for phosphorus limitation, especially in the winter. Further reductions in nitrogen concentration are needed to allow for nitrogen limitation, especially in the spring, summer and fall.

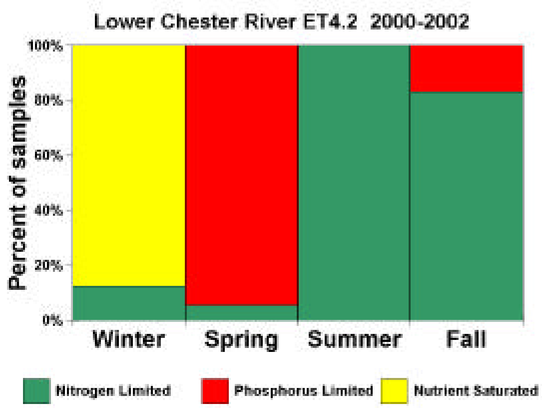
Sassafras River (ET3.1) – On an annual basis, phytoplankton growth is nitrogen limited more than 30% of the time and phosphorus limited more than 5% of the time. In the winter, growth is always nutrient saturated (light limited or no limitation). In spring, growth is nitrogen limited more than 20% of the time and is otherwise nutrient saturated. In summer, growth is nitrogen limited almost 90% of the time and otherwise is phosphorus limited. In fall, growth is nitrogen limited more than 15% of the time, phosphorus limited more than 15% of the time and is otherwise nutrient saturated. Total nitrogen and total phosphorus concentrations are relatively fair and dissolved inorganic nitrogen and dissolved inorganic phosphorus concentrations are relatively good. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is relatively high, indicating that nitrogen is in excess at this station. Reductions in phosphorus would allow for phosphorus limitation in the winter and spring. Reductions in nitrogen would allow for increased nitrogen limitation, especially in the summer and fall.

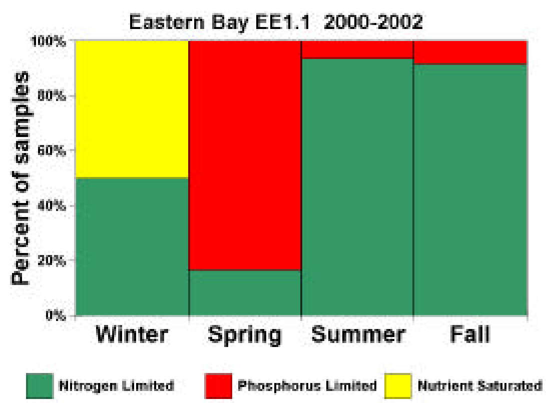




Upper Chester River (ET4.1)- On an annual basis, phytoplankton growth is nutrient saturated (light limited or no limitation) about 90% of the time. Growth is always nutrient saturated in the winter, spring and fall. In the summer, growth is nitrogen limited about 35% of the time, phosphorus limited more than 5% of the time, and otherwise nutrient saturated. Total nitrogen, dissolved inorganic nitrogen, total phosphorus and dissolved inorganic phosphorus concentrations are relatively poor; total phosphorus concentration is improving (decreasing) but dissolved inorganic nitrogen concentration is degrading (increasing). The ratio of total nitrogen to total phosphorus and the ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus ratios are increasing. Further reductions in phosphorus will be needed before winter and spring phytoplankton growth will be phosphorus limited. Reductions in nitrogen will increase the occurrence of nitrogen limitation in the summer, but larger reductions will be needed to cause nitrogen limitation in the fall.

Lower Chester River (ET4.2) – On an annual basis, phytoplankton growth is nitrogen limited more than 45% of the time and phosphorus limited 30% of the time. In the winter, growth is nutrient saturated (light limited or no limitation) about 90% of the time and is otherwise nitrogen limited. In the spring, growth is phosphorus limited almost 95% of the time and otherwise nitrogen limited. In the summer, growth is entirely nitrogen limited. In the fall, growth is nitrogen limited almost 85% of the time and otherwise is phosphorus limited. Total nitrogen and total phosphorus concentrations are relatively fair; dissolved inorganic nitrogen and dissolved inorganic phosphorus concentrations are relatively good and dissolved inorganic nitrogen concentration is improving (decreasing). The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus ratio is decreasing; this ratio is relatively high in the spring, indicating that nitrogen is in excess relative to phosphorus. Further reductions in phosphorus in the spring will further enhance phosphorus limitation. Reductions in nitrogen will further limit summer and fall phytoplankton growth, and would increase the occurrence of nitrogen limitation in the winter.





Eastern Bay (EE1.1) – On an annual basis, phytoplankton growth is nitrogen limited approximately 60% of the time and phosphorus limited more than 25% of the time. In the winter, growth is nitrogen limited about 50% of the time and is otherwise nutrient saturated. In the spring, growth is phosphorus limited almost 85% of the time and is otherwise nitrogen limited. In the summer and fall, growth is nitrogen limited more than 90% of the time and otherwise is phosphorus limited. Total and dissolved inorganic nitrogen concentrations are relatively good and improving (decreasing). Total and dissolved inorganic phosphorus concentrations are relatively good. The ratio of dissolved inorganic nitrogen to dissolved inorganic phosphorus is decreasing. This ratio is relatively low in the winter and spring, indicating that reductions in phosphorus, particularly in the spring, will increase the occurrences of phosphorus limitation. Reductions in nitrogen will further limit summer and fall phytoplankton growth, and would increase the occurrence of nitrogen limitation in the winter.

Appendix C – References

Agresti, A. and B. Caffo. 2000. Simple and effective confidence intervals for proportions and differences of proportions result from adding two successes and two failures. The American Statistician 54:280–288.

Alden, R. W., III, D. M. Dauer, J. A. Ranasinghe, L. C. Scott, and R. J. Llansó. 2002. Statistical Verification of the Chesapeake Bay Benthic Index of Biotic Integrity. Environmetrics, In Press.

Fisher, T. R. and A. B. Gustafson. 2002. Maryland Department of Natural Resources Chesapeake Bay Water Quality Monitoring Program—Nutrient/Bioassay Component—Covering the Period August 1990 – December 2001—May 2002 Report.

Ranasinghe, J. A., L. C. Scott, R. C. Newport, and S. B. Weisberg. 1994. Chesapeake Bay Water Quality Monitoring Program, Long-term Benthic Monitoring and Assessment Component, Level I Comprehensive Report, July 1984-December 1993. Chapter 5: Baltimore Harbor Trends. Prepared for Maryland Department of Natural Resources, Tidewater Ecosystem Assessments, by Versar, Inc., Columbia, Maryland.

Scott, L. C., J. A. Ranasinghe, A. T. Shaughnessy, J. Gerritsen, T. A. Tornatore, and R. Newport. 1991. Long-term benthic Monitoring and Assessment Program for the Maryland Portion of Chesapeake Bay: Level I Comprehensive Report (July 1984-April 1991), Volume I –Text. Prepared for Maryland Department of Natural Resources, Tidewater Ecosystem Assessments, by Versar, Inc., Columbia, Maryland.

Van Belle, G. and J. P. Hughes. 1984. Nonparametric tests for trend in water quality. Water Resources Research 20:127-136.

Weisberg, S. B., J. A. Ranasinghe, D. M. Dauer, L. C. Schaffner, R. J. Diaz, and J. B. Frithsen. 1997. An Estuarine Benthic Index of Biotic Integrity (B-IBI) for the Chesapeake Bay. Estuaries 20:149–158.